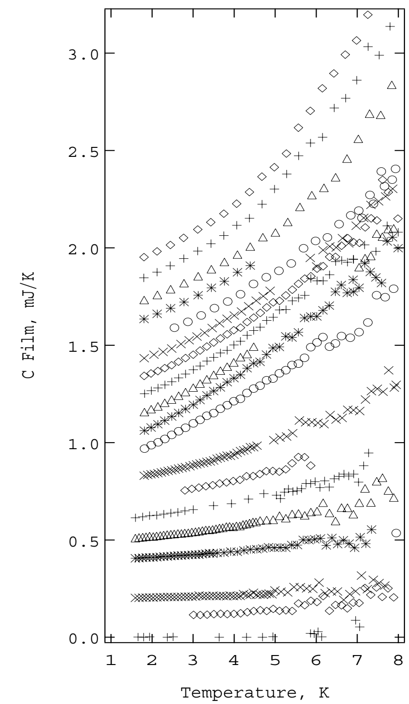
Novel 1- and 2-dimensional Systems

Oscar E. Vilches and Larry B. Sorensen, U. of Washington, Seattle, WA. DMR 0245423

The main purpose of our research effort is to measure and understand the thermal and structural properties of many different substances deposited (physisorbed) on the walls of carbon nanotubes and nanotube bundles. After deposition, the adsorbed substances form novel 1- and 2-dimensional systems whose properties can be compared to many soluble, and inspire new, statistical mechanics models. These novel systems may lead to the discovery of new fluids at very low temperature, test the prediction of absence of phase transitions in 1-d matter, and to a better knowledge of materials for the efficient storage of molecular hydrogen.



Shown above is a comprehensive set of heat capacity measurements of hydrogen adsorbed on carbon nanotube bundles, at different coverages over the first molecular layer (from presentation at Quantum Fluids and Solids, 2004, Trento, Italy).

Atomic Helium and molecular Hydrogen in their condensed state at low temperatures are some of the most studied materials that show quantum mechanical features in a macroscopic scale. When plated on surfaces, one can observe how these features change with dimensionality, most of the time in very significant ways. For example, condensed two-dimensional molecular hydrogen films remain liquid down to 5.7K above absolute zero. This is a reduction of 8K from three-dimensions. We are exploring the consequences of further reducing the dimensionality to one, by using properties of carbon nanotube bundles as substrates. Both helium and hydrogen are predicted to remain in the liquid state down to absolute zero temperature. While this may turn out to be impossible in real systems, our studies are paving the way for the discovery of new and exciting fluids. Along the way, we are learning of how substrates affect the ideal one-dimensional behavior, obtaining information about thermal and structural properties of both nanotubes and the two substances we are studying. Preliminary results from these studies have appeared in the Journal of Low Temperature Physics, Volume124, pages 115-120, in 2004.

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Education: During this second year of our award many undergraduate and graduate students have contributed to our effort:

Graduate: Tate A. Wilson (PhD August 2004, Post-doctoral fellow with R. Hallock at U. of Massachusetts, Amherst), and S. Ramachandran, 3rd year in graduate program

Undergraduate: Damien Ramunno-Johnson (BS,'04, now at UCLA), Eric Higgins (BS, '04, now at UC Irvine), Jeff Schneble (BS, '04, now at Oxford U., England), Russ Horn (BS, '04). Kevin Dillon, Julio Davis, and Ashley Batchelor (juniors) will continue working in the group during 2004-05.

Societal Impact: Research on nanometer size materials is at the forefront of current pure and applied work. Our own contributions have impact on:

A) The training of future pure and applied scientists and technical workforce on the handling and properties of nanoscale materials,

B) The possibility of finding new ways to store molecular hydrogen for the development of ultra light weight fuel cells.

C) Exciting K-12 students and their mentors with results from physics at low temperatures using nano- to micro-meter size materials.